State of the Honeybee: 2021

FROM THE BEST BEES COMPANY

The Best Bees Company
bestbees.com

TABLE OF CONTENTS

HOW ARE THE BEES DOING?

As beekeepers, we are often asked by our clients, friends and family: “So, how are the bees doing these days?”

This report is designed to help you better understand the conditions that exist, what scientists and beekeepers are doing, and some of the promising programs that we hope will lead, over time, to a radical improvement in bee health.

A queen bee and her attendees on a frame of build-out comb.

Why Bees Matter

Why should we all concern ourselves about the health of bees? After humankind, the most influential organism on the planet may be the honeybee. Honeybees helped us build modern civilization, their health is an indicator of the health of the environment, and the data we derive from their interaction with the ecosystem may help us to save it.

There are as many as a *trillion* honeybees, and for almost two decades, their very existence has been in jeopardy.

No other animal has such a positive impact on the environment, the economy, and our food supply. Without bees to pollinate them, we'd lose more than 75% of our food crops. Agriculture-dependent economies would collapse. Much of the web of life built around flowering trees and plants would go into terminal decline.

The UN General Assembly recognized the importance of bees and beekeepers not only to the global food supply but to the economy at every level, seeing beekeeping as a way to build sustainable agriculture and employment in developing communities around the world.

Honeybees have been instrumental in the creation of contemporary civilization. Urbanization and a global economy are dependent on industrialized agriculture, and much of that requires honeybees for pollination. But urbanization, globalization and industrialization have put extreme pressure on pollinators. Habitat loss, the use of poisonous chemicals, the spread of pestilential species through global trade, have had a severe effect on all forms of pollinators—butterflies, moths included—but none has suffered more than the honeybee.

Know Your Bee History

Over 20 years ago, beekeepers in Europe began to report the surprising loss of bee colonies. Hives that had long prospered saw their worker bees vanish, and without them, their colonies were perishing. In 2006, the phenomenon was seen in the U.S. Word quickly spread that a new and dangerous condition existed: Colony Collapse Disorder (CCD). Things were so dire that some predicted near extinction for honeybees within a few years.

Over the past decade, we've learned what factors were causing CCD, and while we haven't been able to eliminate CCD entirely, the threat of extinction has eased.

The problems that caused it, though, still exist, and their combined effect destroys more than 40% of all honeybee colonies annually.

With mortality rates this high, beekeepers cannot risk business as usual. New techniques in queen breeding, colony care, and pest treatment need to be tested, and when successful approaches are found, they must be implemented on a localized basis.

People have been keeping bees for thousands of years. It was a common practice throughout the ancient world, starting at least as early as 2500 B.C.E.

5 WAYS YOU CAN HELP

1. Keep bees. With almost half of all colonies lost each year, we need more bees to sustain a healthy environment. If you work with The Best Bees Company, your bees will do double duty: they'll help pollinate trees and plants, and the data we capture from your hives will help us in our work to improve bee health around the world.

2. Plant pollinator-friendly gardens. Habitat loss is one of the main causes of bee decline. Incorporating pollinator-friendly plants—especially native plants—into your garden or landscape design will provide much-needed nourishment for pollinators in your area.

3. Avoid the use of pesticides and herbicides. Pesticides and herbicides can weaken and even kill bees. There are many organic approaches you can use instead, that will help you control weeds and pests.

4. Learn what bees are pollinating in your area. Data from HoneyDNA® reports will tell you what plants and trees the bees are pollinating, and how diverse the local floral system is. Diversity is key to bee health—the more species they pollinate, the better their health. Information from HoneyDNA can help you and your community know what to plant, identify the presence of rare or invasive species, and can even inform disaster preparedness efforts.

5. Advocate for bees. Use your voice to share information about bees. Spread the word on social media, talk to your friends and family. Look around at the physical spaces and resources you have, and what can be done with them. Ask your employer: what are we doing with that empty rooftop? Tell your elected officials you want them to protect more open space, stop using pesticides and herbicides, and plant native flowering plants in parks and public spaces.

State of Honeybees Today

After a decade of precipitous declines, the total number of honeybee colonies in the U.S. stabilized, and for the past five years, we've experienced only minor increases and decreases. By the end of 2019, there were 3.02 million honeybee colonies in the U.S. In April 2020, that number dropped to 2.98 million.[1]

These totals mask the ongoing battle to replace lost hives, which continues to be a big issue, with more than 40% of all honeybee colonies lost each year in the United States.[2]

SURVIVAL RATES

Overwintering—the number of honeybee colonies that survive from October to April—was particularly challenging this year. While Best Bees' managed hives had survival rates of 58% in Denver, 56% in New York, 47% in Chicago, and 40% in DC—all near or above the national average—we had only 38% in Pittsburgh, 28% in Boston and 26% in Seattle. In the Bay Area and LA, where harsh winters are not a factor, we had much better results, with a 100% survival rate from the prior season.[3]

Preliminary analysis from other national beekeeping research associations show similar conditions for the 2020-2021 season. An estimated 32.2% of the total aggregate of managed honeybee colonies in the United States were lost, which was an increase of 9.6% over the previous overwintering losses. During Summer 2020 (1 April 2020 – 1 October 2020), an estimated 31.1% of managed colonies were lost.[4]

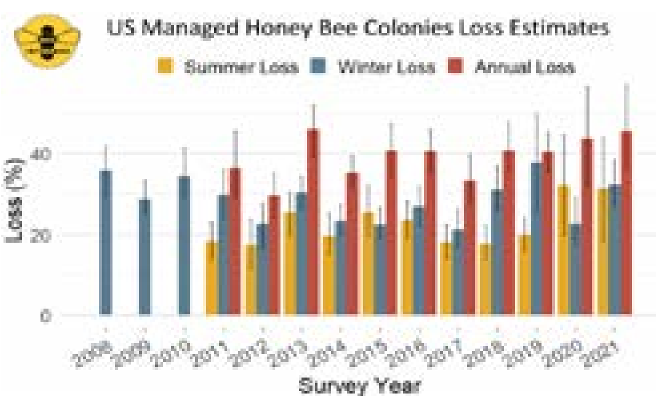

Figure 1: Seasonal honey bee colony loss rates in the United States across years. Annual loss estimates (from one 1 April to the next 1 April) combine winter (1 October – 1 April) and summer (1 April – 1 October) losses. The loss rate was calculated as the total number of colonies lost divided by the number of colonies "at risk" during the season. Colonies at risk were composed of viable colonies and new colonies made or acquired, while excluding colonies sold or parted with. © Bee Informed Partnership

Hive replacement was an issue for beekeepers last spring. COVID-19 plus severe weather conditions in the Southeast, where most commercial bee rearing occurs, slowed the delivery of new queens and new bees to our apiaries. Fortunately, by mid-June of 2020 we received all the replacement queens and bees we needed, and our beekeepers—who were considered essential workers—labored overtime to catch up, regenerate lost hives, and establish new colonies for dozens of new clients. Because of these delayed deliveries, many of our hives got a late start and missed some of the abundant flow of nectar and pollen that occurs in spring, reducing their honey stocks—one possible reason for above average colony loss this winter.

While weather and overwintering were issues for all beekeepers last year, we continued to see success in our approach to mite treatments, and to better address local conditions we initiated our own queen rearing and bee sourcing programs.

VARROA MITE TREATMENT

When we began operations back in 2010, we were concerned about the harmful impact of chemicals used in industrial agriculture on bees and hoped we could find organic treatments for varroa mites, one of the primary causes of colony loss. We quickly learned that organic solutions that existed at the time, such as Hop Guard, were only marginally effective, and so amended our policy and carefully tested several promising chemical treatments that appeared to have no negative effect on bees.

Through partners in the beekeeping community, we learned that Formicpro, a low-toxicity synthetic treatment, was getting good results in mite control. We ran a controlled study and found that what others had seen anecdotally was true: Formicpro successfully reduced mite infestation in 83% of our hives.

Data from this and other tests we conducted has shown us that a three-step process, beginning with oxalic acid treatment of new bees before they're introduced to a hive, followed by Formicpro in early summer, ending with oxalic acid in the fall, is the most effective approach. The combination used in this way is both safe and effective, as it applies a strong solution—oxalic acid—that adult bees can tolerate, both early and late in the season, when few brood cells are present, and uses Formicpro, a strip which emits formic acid to fumigate the hives, which does little harm to brood cells, but can permeate them and kill mites that feed on them.

> "With mite reproductive cycles so short, the probability of treatment-resistant mutations is pretty high. This makes for a kind of arms race where we need to constantly look for new solutions to stay ahead of them."

Sean Smith, Regional Director at Best Bees

In our quest to find even safer and more effective treatments, we're looking at Hive Alive, an organic solution made of essential oils and seaweed. Indications from other beekeepers suggest it may be effective, but we'll need to conduct extensive tests to learn if it can be used as a substitution for our current synthetic treatments.

New treatments that may eliminate the need for chemical based eradication methods are on the horizon. The spores of *metarhizium brunneum*, a common fungus found in soils around the world, has been shown to kill Varroa mites, while leaving bees virtually untouched. A research team in the Department of Entomology at Washington State University developed a strain of this mushroom that survives higher temperatures, meaning it can last in hive heat. While this still needs to be approved by the EPA, it's a promising study that may change the way we treat beehives in the future.[5]

Varroa Mite on the back of a honeybee

QUEEN REARING

As we've expanded across the country, we've found each new area we work in has its own unique set of challenges: in southern California, we've encountered aggressive, Africanized bees; in Boston, Denver and New York, the winters can be harsh; in the Bay Area, climate and the amount of nourishment available can vary dramatically between micro-climates just a few miles apart. Ideally, we'd be sourcing queens and bee stocks in each, but most of the commercial breeders are currently in the Southeast.

Last year we initiated queen rearing pilot programs in the Bay Area and Boston, with New York to be added later this year. Our ultimate goal is a sustainable bee breeding operation, with bees raised locally, to meet the specialized needs of each environment.

Our initial efforts began with strong colonies we flagged from our database based on calmness, brood size, honey production, and limited presence of mites. From these, we took small splits of queenless bees, grafted eggs into queen cells in a queen apiary, gave them 24-48 hours to take, moved them to a finisher hive, then isolated the queens in nuc (mating hive) where we allowed them to hatch and mate. We did this in areas with few neighboring hives so as to control which drones they mated with, increasing the likelihood the queens we rear will pass along desirable genetic traits.

Interested in more about our queen rearing efforts? Read our blog, "Queen Rearing Programs Around The World."

> "We have amazing data on our hives like brood size & consistency, mite resistance, honey production, survival rates. This data will help us select larvae with the best genetic potential, raise our own crop of queens, and monitor the success of their hives."

Nicole Voraka, Head Beekeeper of the Bay Area at Best Bees

Reports from the Frontline of Bee Science

As both scientists and beekeepers, The Best Bees Company is in a unique position to study bees, test new approaches to beekeeping, and continuously improve our beekeeping operations. We're proud to be part of the beekeeping community and are eager to partner with others to advance our collective knowledge and share best practices.

We've worked with scientific leaders, such as NASA, MIT and the National Geographic Society, as well as small but innovative beekeepers and breeders across the country, to develop and test hypotheses about bee behavior and health, and beekeeping practices that will improve their condition.

We'd like to share a few of the studies we're currently working on to give you an idea of the scope of our scientific work, what we're learning, and why we're optimistic about the future of bees.

Foraging Habits & Habitat

We can tell which species of plants and flowers a given honeybee hive forages from, and in what percentage, through a process we designed to analyze the pollen content in a drop of honey: HoneyDNA®. When a customer orders an analysis of their hive's honey from us, we also add the results to our ever-growing database for future pattern recognition exercises. We've found that most bee colonies are pollinating scores, even hundreds of different species each season.

The process of analyzing DNA in honey is similar to the forensic science used to solve crimes—even tiny traces of material leave genetic signatures which can be used to identify their sources. Here's how it works:

1. A small sample of honey is drawn from a jar or directly from the field.
2. Reagents separate plant DNA from sugars and other materials and are spun out in a centrifuge.
3. The microscopic particles are amplified and copied for analysis.
4. The sequence of molecules is classified and recorded.
5. The molecular sequences are matched to a global database of plant genomics.
6. The report is labeled with scientific names and appended with common names.

Through this process we learn which plants bees have pollinated and their contribution to honey produced. We analyze the result of individual hives, as well as hives in different geographies.

The results can be quite surprising: a hive in a densely populated neighborhood in downtown Boston produced honey from 411 different species of trees, shrubs and flowering plants—a record for Best Bees colonies; a hive in an affluent exurban community with large swathes of landscaped properties produced honey from only 52 species.

We've been gathering data for 6 years and accumulated 502 unique plant species in our HoneyDNA samples from honeybees across the U.S. In 2020, we discovered 30 new species, bringing our library to 532. Some of the new species included:

Black greasewood
Radiator plants
Southern blue gum
Western cypress
Iron tree
Bristly fiddleneck
Southern blue gum
Western cypress
Mountain hydrangea
Primrose-willow
Muscadine
Pineapple
Creeping bellflower
Spiny broom
Red bayberry
Black hawthorn
Asinchete
Dayflowers
Burr cucumber
Red clover
Prairie clover
Yellow sweet clover
Butterfly-bush
Deervetches
Mugworts
Old man's beard
Hops
Coastal sweetpepperbush
Blackjack oak

Urban areas offer a much more diverse range of plants for pollinators, and by comparing HoneyDNA with data on colony health, initial research suggests that that diversity correlates to healthier hives.

BIODIVERSITY MAPPING

HoneyDNA can give ecologists and planners a much more precise look at the local floral environment than possible through human observation. HoneyDNA can tell them about the presence of rare and endangered species, and it can alert them to the introduction of invasive species. Through longitudinal studies, we can learn which plants are thriving and which are declining, and whether we're losing essential genetic diversity.

HoneyDNA can even help with disaster response. Studying HoneyDNA before and after hurricanes in Puerto Rico, we learned which plant species were most devastated by storms, and which had the fastest recovery. This information can be used by local planning authorities to guide them in what to plant to mitigate environmental damage and to accelerate regeneration.

In 2020, we took samples from regions impacted by the California wildfires. After the fire, we see a significant increase in foraging from a wide range of stone fruits, among other shifts.

These are preliminary findings. We still have many questions about what the data means for the region, for bee health, and the ecological preservation of pollinator habitat. We will continue to analyze the data and work with local authorities to share our findings and help planners make informed decisions about sustainable development.

HIVE 1 El Sobrante, CA Before fire (2019)		**HIVE 1** ElS obrante, CA After fire (2020)	
38.13%	Buckthorn	68.37%	Stone fruits
35.67%	Black greasewood	21.3%	Willows
17.70%	Wild buckwheat	2.36%	Rosemary
8.51%	Stone fruits	1.73%	Medicks

HIVE 2 El Sobrante, CA Before fire (2019)		**HIVE 2** ElS obrante, CA After fire (2020)	
45.59%	Purple horn-tooth moss	33.59%	Stone fruits
32.64%	Rose family	32.68%	Rose family
21.77%	Medicks	15.24%	Willows
		3.75%	Buckthorns

Flames from a backfire consume a hillside as firefighters battle the Maria Fire in Santa Paula, Calif., on Friday, Nov. 1, 2019. (AP Photo/Noah Berger)

BREEDING THE BEST BEE

Every visit by a Best Bees beekeeper is logged into our database using our proprietary beehive management platform we call Bzzz. This allows us to identify patterns across the entire database, as well as within different geographies. It also allows us to track specific indicators of health and survival potential for individual colonies.

In preparation for our queen rearing initiative, our analysts tracked the performance in fall of 2020 of hives in the Bay Area and Boston across three key factors:

1. Behavior—are the bees calm, busy, or protective;
2. How many Varroa mites are present—none, below threshold, or above threshold;
3. Likelihood of survival, based on beekeeper observation, population, honey yield and brood patterns.

Using these factors our analysts were able to identify a small set of "super star" colonies that have the best characteristics for queen rearing—they were calm, had below threshold of mite presence, and a strong chance for survival. With a possible concern that very calm colonies might have issues overwintering, they identified other colonies that were busier, but were above average on all other factors.

From this pool of strong candidates, we're now extracting larvae and bees for queen rearing, and will track the performance of these new colonies to see if the factors we chose and the hives we used yield colonies that are more mite resistant and better able to overwinter.

"Getting the right characteristics is a real balancing act—we need calm, productive bees, who are mite resistant and, for northern hives, cold tolerant. Our data has identified some very attractive hives to work with."

Shay Willette, Head Beekeeper at Best Bees

A QUEEN'S REIGN

In years past, we've been inclined to let our queen bees lay for as long as they are productive. It's more efficient than replacing them every year or every other year, as is common in the beekeeping world. Queens that survive for two, three, even four years are demonstrating strong genes that we want to pass on to colonies, and our clients become attached to them—they see the queen as a kind of mother-force, and often worry that replacing her will be harmful for their hive.

We've found a downside to letting queens "reign" too long: their brood production can become weak and irregular, or even stop altogether. If that happens later in the season, a replacement queen may not be able to make up for the lost bees and honey production that comes with a full-sized colony.

Over the past year, we've begun to study the reign of our queens and have found that few actually make it to three years, so the problem with weak, older queens may be relatively rare. To assure we optimize their value to colonies, we're establishing a system for identifying aging queens that need replacement.

Some colonies create their own when they sense a new queen is needed. Among colonies where we intervene and manually introduce a new queen, we color mark her to know when she was introduced and her age. We supplement that with brood pattern data our beekeepers gather with each visit, rating production on a 1-5 scale. When ratings steadily decline, we become concerned; when they fall below a 3 rating we replace the queen.

"Brood patterns are one way we gauge whether or not a queen needs to be replaced. There are factors that we use as indicators such as behavior towards the queen, her physical health, supersedure cells, and disease in broods."

Shay Willette, Head Beekeeper at Best Bees

BEES IN SPACE

As a consultant to the MIT Media Lab, our founder, Noah Wilson-Rich PhD, is often called to advise on research projects involving bees. This past year, a group of students was offered an opportunity to place bees on a reusable rocket test with Blue Origin, the rocket company founded by Jeff Bezos. With Noah's help, a test was designed that would study how bee queens and their workers would fare in the stressful environment of a rocket launch, zero gravity and reentry.

Two capsules were created to house one mated queen each, plus two groups of worker bees to support and care for them. One of Noah's colleagues shared queens from his breeding program that represented the most robust, healthy bees possible so that there would be no question of the viability of the queens used. The rocket launch test was performed, and the test bees were recovered in the Texas desert after touchdown.

The students' hypothesis—that zero-gravity would allow bees to produce combs in every direction—was proven true. The queens and their worker bees not only survived the experience, but without gravity to restrict them, began to produce combs in all directions—both vertically and horizontally.

"In the future, as we set up outposts on the Moon, Mars and beyond, bees will be essential to how space pioneers sustainably feed themselves. This first test showed us that bees can exist, even thrive in space—which is great news for space programs to come."

Noah Wilson-Rich, PhD, Best Bees Founder and CEO

Maiden Flight represents the first space module of its kind built specifically to cater to queen bees. The hybrid-ecology of the capsule was created to take into account the distributed and uniquely non-human nature of bee biology, in order to consider how to extend the bee reproductive system for environmental extremes. This aim is reflected in the structure of the capsule interior, which was assembled by humans and augmented by the bees' natural fabrication. Overall, this project epitomizes the Mediated Matter Group's ethos – design for, with, and by Nature – by placing the bee at the center of the design process. — Mediated Matter, MIT Media Lab.[6]

Honeybees in the Maiden Flight metabolic pod.

COLONY CROWDING

We've been encouraging people to keep bees, especially in metropolitan areas that large commercial beekeepers have traditionally avoided, to help build up the nation's supply of bees, and to supplement the native pollinators in those areas.

As the number of hives has grown, some of our craft beekeeping colleagues have voiced concern that a situation called "colony crowding" might occur, where the carrying capacity of the area is exceeded, leading to hive robbing, diminished honey stocks, weakened hives, and a decline in native pollinators.

Indeed, commercial beekeepers who can bring in hundreds of hives to support seasonal agriculture are more likely to create such extreme effects. On the other hand, independent and small-scale beekeepers who keep up to a dozen or so hives on a given property, are creating less of a risk, and in fact can create more value by monitoring the local biodiversity of a given area, mite levels, and other data.

Does the presence of honeybee hives negatively or positively affect other bees in the area?

Of studies examining pollinator competition, the evidence is inconclusive. Results showed 53% reporting negative effects on wild bees, 28% reporting no effects, and 19% reported mixed effects (varying with the bee species or variables examined). Equal numbers of studies examining plant communities reported positive (36%) and negative (36%) effects, with the remainder reporting no or mixed effect.[7]

In 2020, we conducted a study to measure honey production, robbing events and colony behavior (calm, busy, defensive) in a five-mile radius around six communities, rated by the density of hives under our management. We did not observe significant differences between densely, moderately or sparsely honeybee-populated areas. This tells us that at the current density, our honeybees are not correlated to colony crowding.

We would like to continue to study population density and incorporate additional factors, such as disease and the health of wild pollinators. Our hypothesis is that more pollination from honeybees generates more foraging habitat for all pollinators, as put forward in *WIRED*: "Why Some Ecologists Worry About Rooftop Honey Bee Programs."[8]

"When compared to areas with less beehive density, our urban hives don't appear to be negatively affected by increased competition."

Bronia Bogen-Grose, Researcher at Best Bees

New Projects for 2021-22

Our beekeepers are constantly bursting with ideas for new research projects to answer the myriad questions that come up during their work. Each study inevitably leads to more questions, and this is what our team is hoping to accomplish in the next few years.

Understanding Brood Gaps: Brood gaps can exist for two reasons—queens can be distressed because of mite treatments, or some bees (Carniolan) do it naturally in response to the seasonal availability of pollen and nectar. While it is fairly common and not a concern, we would like to study it more to understand why it happens. Is it due to genetic traits based on resource management? Or Hygienic behavior? How do we tell the difference?

Colony Crowding: The research here has been inconclusive and contradictory around the world. It's clear to us that while Boston is still under its carrying capacity, we don't fully understand the breadth of the issue. Is there a limit on how many colonies a given environment can support? Does it make a difference where the colonies are? We also are interested in how growing populations of domestic honeybees may impact native species. In order to make management choices that are best for both honeybees and native pollinators, we are supporting research and gathering data to answer questions like: do honeybees and native bees compete for resources? How does it impact plant life? Pollinator life?

Location Based Behavior: It's entirely possible that the location of a beehive can impact the behavior of a colony. Not just where in the world the bees are, but specific details. How does wind, shade, or the direction the hive is facing affect the calmness of a colony? With access to hives in a variety of locations around the U.S., we can start to collect this data and make choices on where to put future hives based on our findings.

Climate Change: Climate change has drastic impacts on every facet of life, so looking closer on its impact on honeybees is imperative. Specifically, we want to learn more about the effects of drought and periods of nectar dearth. How exactly is that affecting our honey bees ability to overwinter in northern environments?

Colony Collapse Disorder: The imminent threat may be easing, but we're still aware of the impacts of CCD. We found five hives that died this year with similar symptoms to CCD. Is it coming back? Should we be concerned?

Treatment Effectiveness: Being able to intervene in a hive's health can be a lifesaver for many colonies, however, there are still tests we need to run to understand the impact. How can we test and analyze the efficacy of Oxalic Acid, Hive Alive and Xentari?

Conclusion

We are encouraged by our team of next-gen beekeepers who are passionate about the bees and continue to ask great questions that inspire more research projects that help us better understand the state of the honeybee today. By carefully tending for and meticulously tracking data from each visit, the dedicated team is what makes these findings possible.

We continue to be hopeful about the future of bee health, which we are learning more about each year thanks to citizen science. All this data is made possible by our clients' support. Each hive, whether at a home or a business, provides invaluable information with the power to drive new innovations in the world of bees. The Best Bees Company is uniquely positioned to collect data from all around this country, through a network of data-yielding beehives.

Best Bees Beekeepers recording beehive data.

Who Are We?

The Best Bees Company was founded to bring science and beekeeping together to improve bee health and expand the bee population.

We use data collected by our beekeepers to inform our research and apply that information derived from thousands of hives across the country to help our beekeepers implement more effective practices.

We manage hives in over a dozen metropolitan areas, and maintain the largest database on bee health, bee behavior and beekeeping treatment in North America.

Our work, which is helping to transform beekeeping, would not be possible without the support of our clients. If you recognize the importance of honeybees to the world, we urge you to join them in taking action. Whether you manage residential or commercial skyscrapers or are a small backyard gardener, there are many things you can do to help, from keeping bees on your property to spreading the word about the plight of bees and the need for action.

Our operating regions:

Boston
Chicago
Denver
Houston
Los Angeles
New York
Pittsburgh
Portland
Salt Lake City
San Francisco
Seattle
Washington DC
Philadelphia
Dallas

Interested in bringing bees to your home or workplace? Please contact us for a virtual site assessment.

bestbees.com | info@bestbees.com | (617) 445-2322

Glossary

Brood: In beekeeping, bee brood or brood refers to the eggs, larvae and pupae of honeybees.

Brood gaps: Random or scattered broods can be indicative of failing or elderly queens, disease, or that a colony is not large enough to care for all the brood.

Bzzz: We created Bzzz, a proprietary hive management system, to ensure the health of each beehive was recorded and ready for research.

Colony crowding: A concept based on the theory that a given natural environment has reached its carrying capacity for honey bees.

Colony Collapse Disorder (CCD): Colony Collapse Disorder is the phenomenon that occurs when the majority of worker bees in a colony disappear and leave behind a queen, plenty of food and a few nurse bees to care for the remaining immature bees and the queen (EPA).

HoneyDNA®: We pioneered the process of identifying the exact percentage of various pollen species found in honey through advanced genomic sequencing. Understanding where bees foraged reveals which plants best feed pollinators in the local environment.

Mating hive: A lightweight hive that requires only a handful of bees and can be self-sufficient during the whole queen mating season. Made from rigid, double walled and insulated hard plastic. Mating Hive includes: feed chamber, three frames, sliding floor and entrance gate.

Nuc: Short for nucleus hive, a nuc is what beekeepers call a mating hive.

Overwintering: During winter months, colonies become dormant. the queen does not lay for a period of time, giving her a break from laying eggs.

Oxalic acid: An organic compound found in many plants. It is used to treat beehives for varroa mites.

Varroa mites: *Varroa destructor* and *V. jacobsoni* are tiny red-brown parasitic mites that prey on honeybees. They can feed and live on adult honeybees, but rely mostly on larvae and pupae in developing broods, causing malformation and weakened bees. They also transmit viruses.

SOURCES

1 Honey Bee Colonies . United States Department of Agriculture. (2020, August). ISSN: 2470-993X. https://downloads.usda.library.cornell.edu/usda-esmis/files/rn301137d/nc5819380/t148g6070/hcny0820.pdf.

2 University of Maryland. (2019, June 19). U.S. beekeepers lost over 40 percent of colonies last year, highest winter losses ever recorded: Results point to a need for increased research, extension, and best management practices. ScienceDaily. Retrieved August 12, 2021 from www.sciencedaily.com/releases/2019/06/190619142532.htm.

3 Honey bee colonies . United States Department of Agriculture . (2020, August). https://www.nass.usda.gov/Publications/Todays_Reports/reports/hcny0820.pdf.

4 Bee Informed Partnership. (2021, June 23). Loss & Management Survey. https://beeinformed.org/citizen-science/loss-and-management-survey/.

5 Sci-News. (2021, May 28). New Fungus Strain Effective against Varroa Mites in Honeybee Colonies. http://www.sci-news.com/biology/metarhizium-brunneum-strain-varroa-mites-09705.html

6 MIT Media Lab. (2020). Maiden Flight: Designed for the Blue Origin mission. https://mediatedmattergroup.com/maiden-flight.

7 Mallinger, R. E., Gaines-Day, H. R., & Gratton, C. (2017). Do managed bees have negative effects on wild bees?: A systematic review of the literature. PloS one, 12(12), e0189268. https://doi.org/10.1371/journal.pone.0189268.

8 Ball, J. C. (2020, October 2). Why some ecologists worry about rooftop honey bee programs. Wired. https://www.wired.com/story/why-some-ecologists-worry-about-rooftop-honey-bee-programs/.